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(54) Title: METHOD OF AND SYSTEM FOR TRANSMITTING AND/OR RETRIEVING REAL-TIME VIDEO AND AUDIO INFORMATION OVER PERFORMANCE-LIMITED TRANSMISSION SYSTEMS

(57) Abstract

The architecture of numerous networks, including the Internet with its World Wide Web (WWW) browsers and servers, support full file transfer for document retrieval. In order for the WWW to support continuous media, it is necessary to transmit video and audio on demand and in real-time, as well as new protocols for real-time data. The invention extends the architecture of the WWW to encompass the dynamic, real-time information space of video and audio. The inventive method, called Vosaic, short for Video Mosaic, incorporates real-time video and audio into standard hypertext pages and which are displayed in place. Video and audio transfers occur in real-time; there is no file retrieval latency. The video and audio result in compelling Web pages. Real-time video and audio data can be effectively served over the present day Internet with the proper transmission protocol. The invention includes a real-time protocol, called a video datagram protocol (VDP), for handling real-time video over the WWW. VDP minimizes inter-frame jitter and dynamically adapts to the client CPU load and network congestion. The video server in accordance with the invention dynamically changes transfer protocols, adapting to the request stream. The invention also is applicable to other networks using Internet-type protocols such as TCP/IP, including local area networks, metropolitan area networks, and wide area networks.

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METHOD OF AND SYSTEM FOR TRANSMITTING AND/OR RETRIEVING REAL-TIME VIDEO AND AUDIO INFORMATION OVER PERFORMANCE-LIMITED TRANSMISSION SYSTEMS

FIELD OF THE INVENTION

The present invention relates to a method of and system for transmitting and/or retrieving real-time video and audio information. The inventive method compensates for congested conditions and other performance limitations in a transmission system over which the video information is being transmitted. More particularly, the invention relates to a method of transmitting and/or retrieving real-time video and audio information over the Internet, specifically the World Wide Web.

BACKGROUND OF THE INVENTION

"Surfing the Web" has entered the common vocabulary relatively recently. Individuals and businesses have come to use the Internet both for electronic mail (e-mail) and for access to information, commonly over the World Wide Web (WWW, or the Web). As modem speeds have increased, so has Web traffic.

Web browsers, such as National Computer Security Association (NCSA) Mosaic, allow users to access and retrieve documents on the Internet. These documents most often are written in a language called HyperText Markup Language (HTML). Traditional information systems design for World Wide Web clients and servers has concentrated on document retrieval and the structuring of document-based information, for example, through hierarchical menu systems as are used in Gopher, or links in hypertext as in HTML.

Current information systems architecture on the Web has been driven by the static nature of document-based information. This architecture is reflected in the use

of the file transfer mode of document retrieval and the use of stream-based protocols, such as TCP. However, full file transfer and TCP are unsuitable for continuous media, such as video and audio, for reasons which will be discussed in greater detail below.

The easy-to-use, point-and-click user interfaces of WWW browsers, first popularized by Mosaic, have been the key to the widespread adoption of HTML and the World Wide Web by the entire Internet community. Although traditional WWW browsers perform commendably in the static information spaces of HTML documents, they are ill-suited for handling continuous media, such as real time audio and video.

Earlier Web browsers, such as Mosaic, required a user to wait until a document had been retrieved completely before displaying the document on the screen. Even at the faster transfer speeds which have been become possible in recent years, the delay between retrieval request and display has been frustrating for many users. Particularly in view of the astronomical increase in Internet traffic, during especially busy times, congestion over the Internet has negated at least some of the speed advantages users have obtained by getting faster modems.

Video and audio files tend to be much larger than document files in many instances. As a result, the delay involved in waiting for an entire file to download before it is displayed is even greater for video and audio files than for document files. Again, during busy times, Internet congestion would make the delays intolerable. Even in networks which are separate from the Internet, transmission of sizable video and audio files can result in long waits for file transfer prior to display.

Multimedia browsers such as Mosaic have been excellent vehicles for browsing information spaces on the Internet that are made up of static data sets. Proof of this is seen in the phenomenal growth of the Web. However, attempts at the inclusion of video and audio in the current generation of multimedia browsers have been limited to transfer of pre-recorded and canned sequences that are retrieved as full files. While the file transfer paradigm is adequate in the arena of traditional information retrieval and navigation, it becomes cumbersome for real time data. The transfer times for video and audio files can be very large. Video and audio files now on the Web take minutes to hours to retrieve, thus severely limiting the inclusion of video and audio in current Web pages, because the latency required before playback begins can be unacceptably long. The file transfer method of browsing also assumes a fairly static and unchanging data set for which a single uni-directional transfer is adequate for browsing some piece of information. Real time sessions such as videoconferences, on the other hand, are not static. Sessions happen in real time and come and go over the course of minutes to days.

The Hypertext Transfer Protocol (HTTP) is the transfer protocol used between Web clients and servers for hypertext document service. The HTTP uses TCP as the primary protocol for reliable document transfer. TCP is unsuitable for real time audio and video for several reasons.

First, TCP imposes its own flow control and windowing schemes on the data stream. These mechanisms effectively destroy the temporal relations shared between video frames and audio packets.

Second, unlike static documents and text files, in which data loss can result in irretrievable corruption of the files, reliable message delivery is not required for video

and audio. Video and audio streams can tolerate frame losses. Losses are seldom fatal, although of course they can be detrimental to picture and sound quality. TCP retransmission, a technique which facilitates reliable document and text transfer, causes further jitter and skew internally between frames and externally between

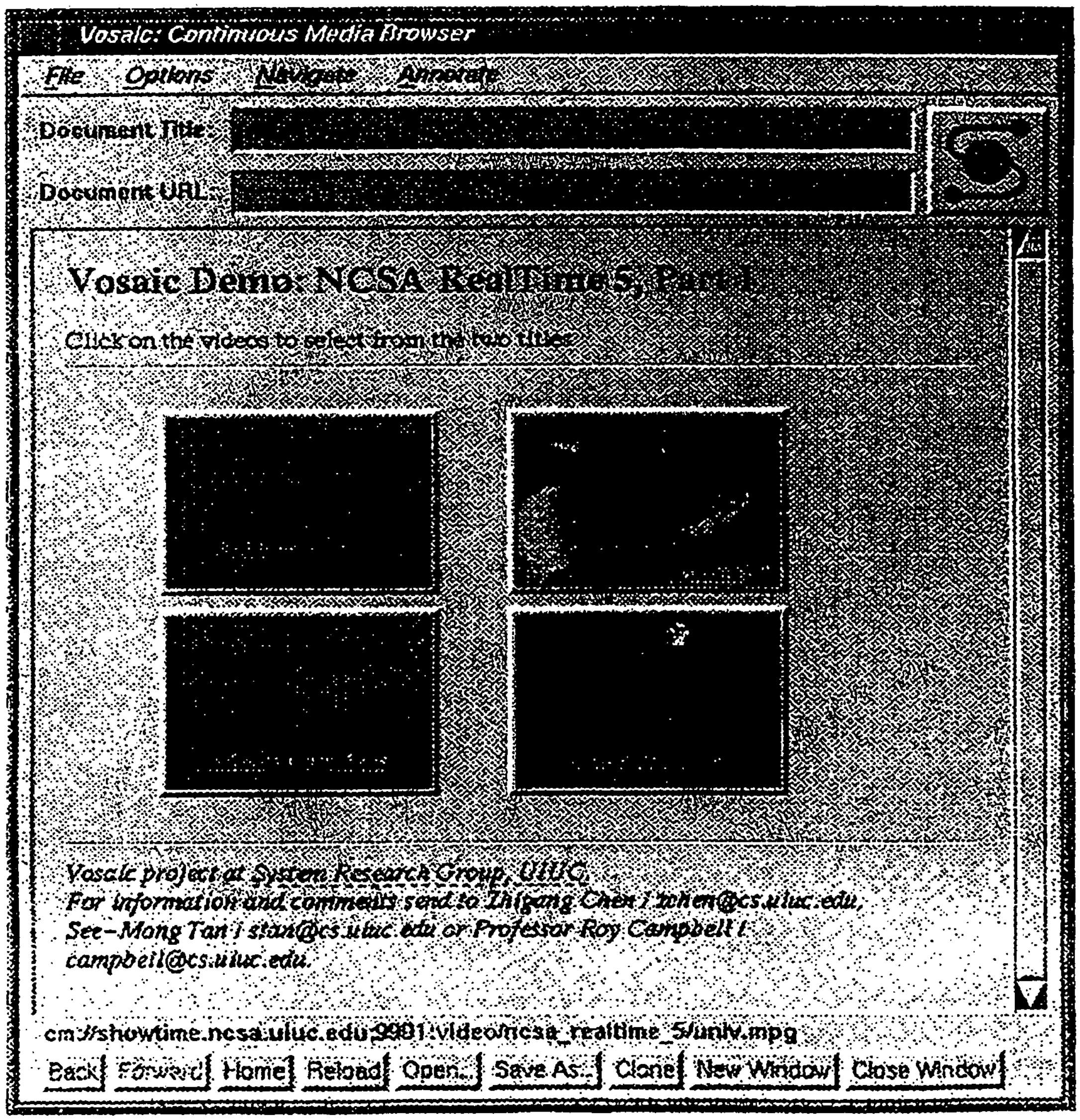

Vosaic: Continuous Media Browser
File Options Navigate Annotate
Document Title:
Document URL:
Vosaic Demo: NCSA RealTime 5, Part I
Click on the videos to select from the two titles
Vosaic project at System Research Group, UIUC.
For information and comments send to Zhigang Chen / zchen@cs.uiuc.edu,
See-Mong Tan / stan@cs.uiuc.edu or Professor Roy Campbell /
campbell@cs.uiuc.edu.
cm://showtime.ncsa.uiuc.edu:9901:video/ncsa_realtime_5/univ.mpg
Back Forward Home Reload Open... Save As... Clone New Window Close Window

FIG. 1

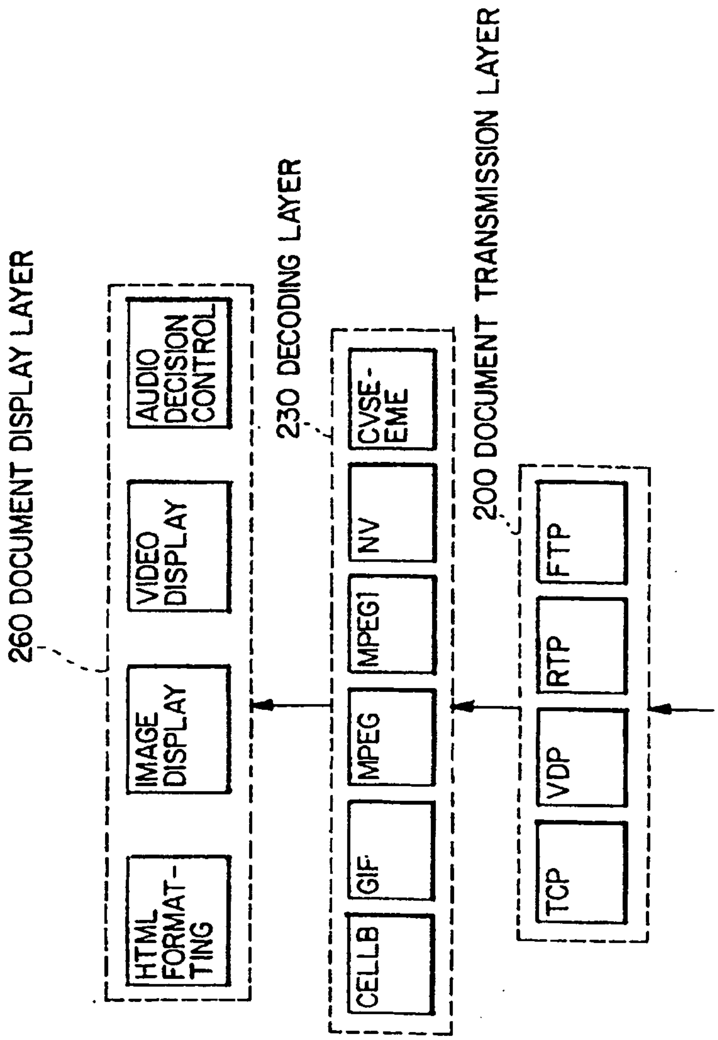

200 DOCUMENT TRANSMISSION LAYER
TCP
VDP
RTP
FTP
230 DECODING LAYER
CELLB
GIF
MPEG
MPEG1
NV
CVSE-EME
260 DOCUMENT DISPLAY LAYER
HTML FORMAT-TING
IMAGE DISPLAY
VIDEO DISPLAY
AUDIO DECISION CONTROL

FIG. 2

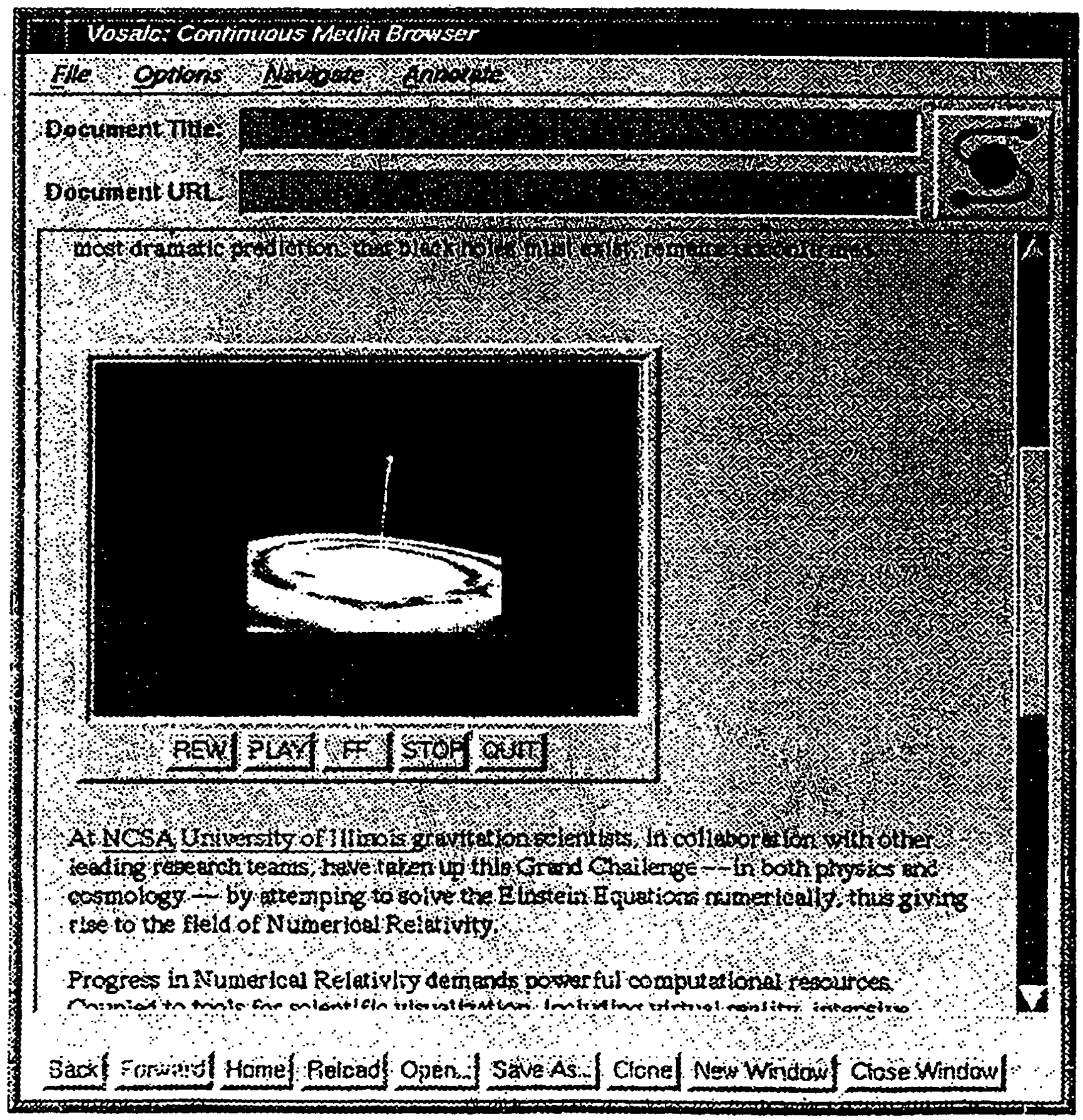

Vosaic: Continuous Media Browser
File
Options
Navigate
Annotate
Document Title:
Document URL:
REW
PLAY
FF
STOP
QUIT
At NCSA University of Illinois gravitation scientists, in collaboration with other leading research teams, have taken up this Grand Challenge — in both physics and cosmology — by attemping to solve the Einstein Equations numerically, thus giving rise to the field of Numerical Relativity.
Progress in Numerical Relativity demands powerful computational resources.
Back
Forward
Home
Reload
Open...
Save As...
Clone
New Window
Close Window

FIG.3

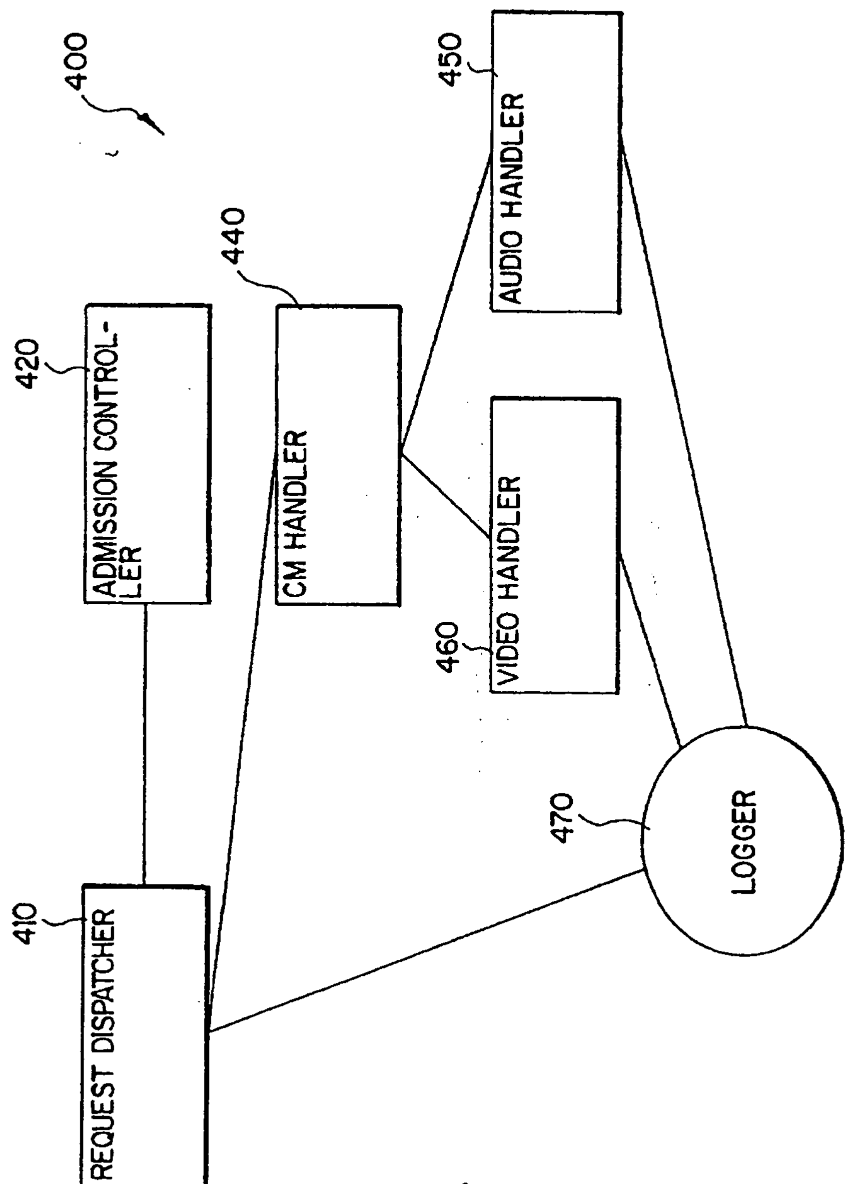

400
410
REQUEST DISPATCHER
420
ADMISSION CONTROL-
LER
440
CM HANDLER
450
AUDIO HANDLER
460
VIDEO HANDLER
470
LOGGER

FIG. 4

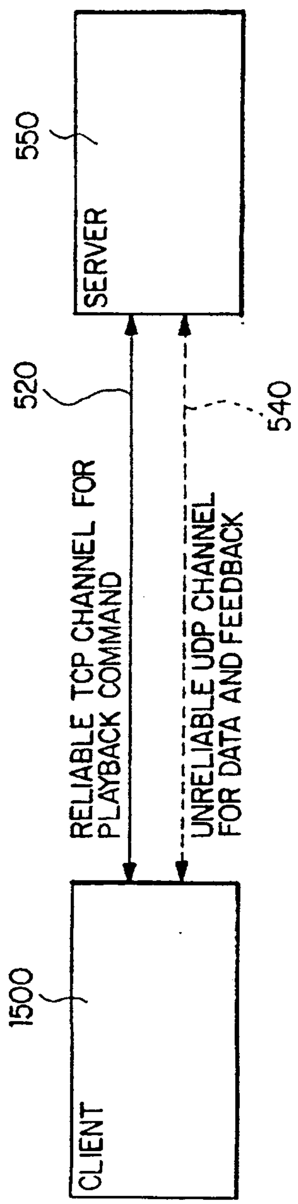

CLIENT
1500
RELIABLE TCP CHANNEL FOR
PLAYBACK COMMAND
UNRELIABLE UDP CHANNEL
FOR DATA AND FEEDBACK
520
540
SERVER
550

FIG. 5

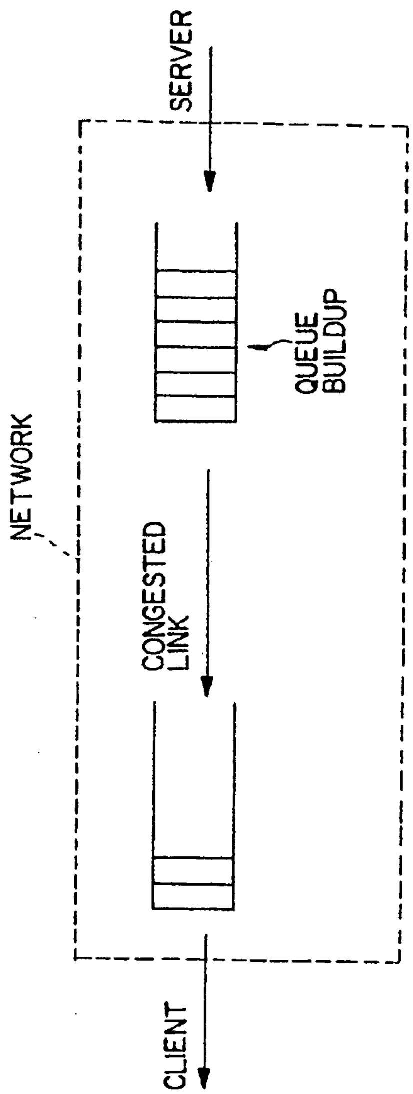

CLIENT
NETWORK
CONGESTED
LINK
QUEUE
BUILDUP
SERVER

FIG. 7

FIG. 6

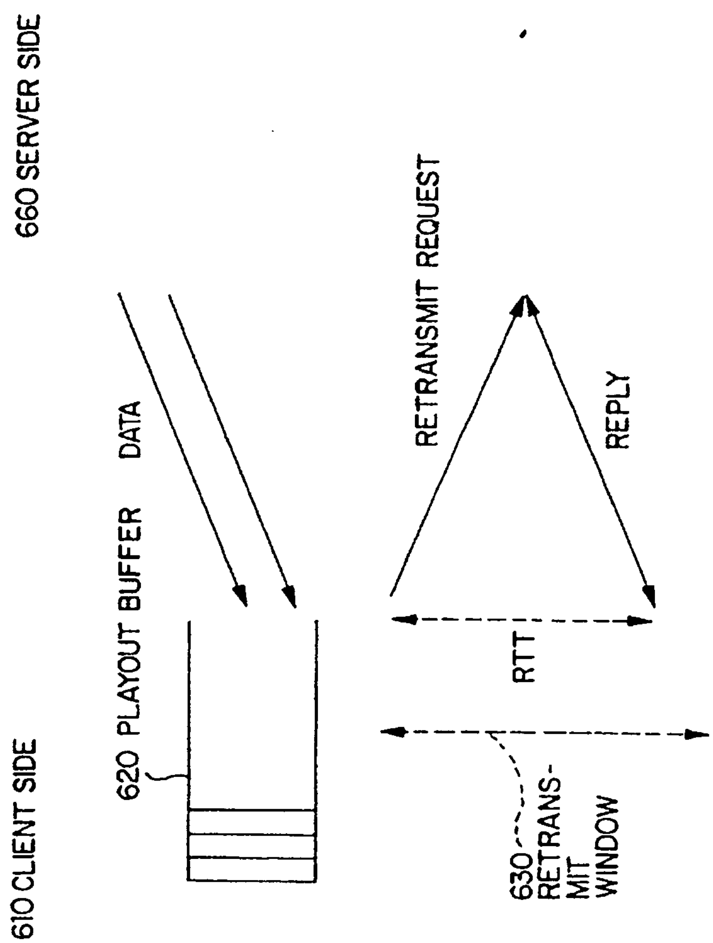

660 SERVER SIDE
DATA
620 PLAYOUT BUFFER
610 CLIENT SIDE
RETRANSMIT REQUEST
REPLY
RTT
630 RETRANS-MIT WINDOW

FIG. 8

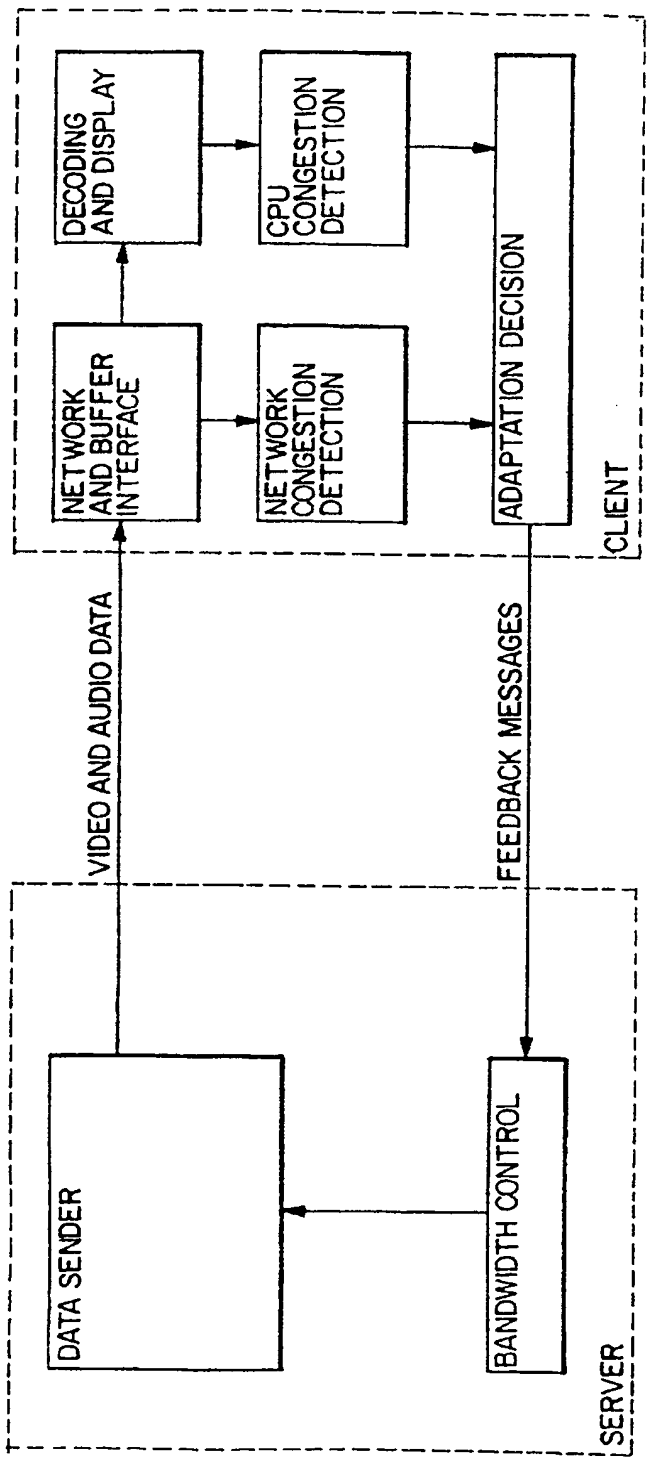

DECODING AND DISPLAY
CPU CONGESTION DETECTION
NETWORK AND BUFFER INTERFACE
NETWORK CONGESTION DETECTION
ADAPTATION DECISION
CLIENT
VIDEO AND AUDIO DATA
FEEDBACK MESSAGES
DATA SENDER
BANDWIDTH CONTROL
SERVER

FIG. 9

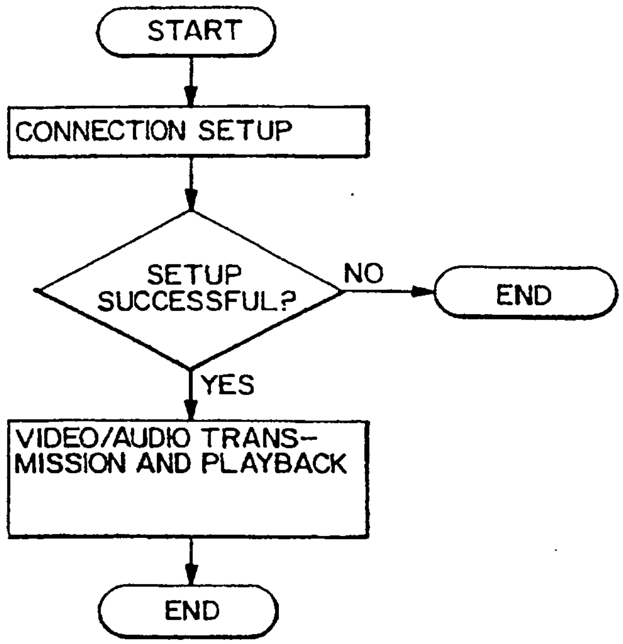

START
CONNECTION SETUP
SETUP SUCCESSFUL?
NO
END
YES
VIDEO/AUDIO TRANS-MISSION AND PLAYBACK
END

FIG. 12

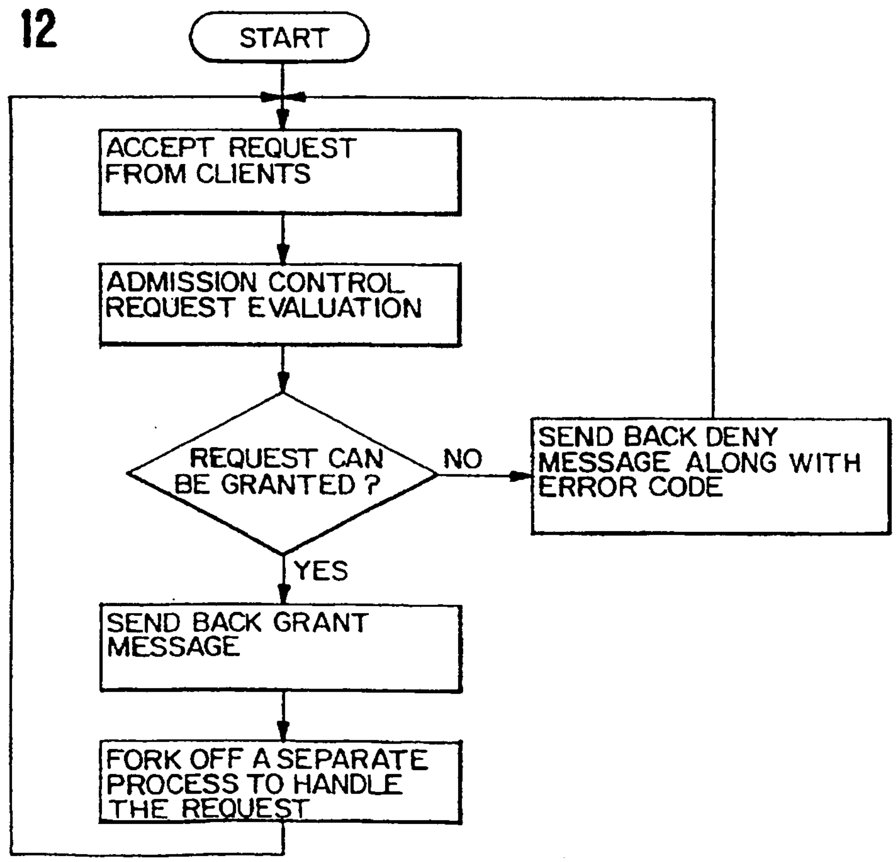

START
ACCEPT REQUEST FROM CLIENTS
ADMISSION CONTROL REQUEST EVALUATION
REQUEST CAN BE GRANTED ?
NO
SEND BACK DENY MESSAGE ALONG WITH ERROR CODE
YES
SEND BACK GRANT MESSAGE
FORK OFF A SEPARATE PROCESS TO HANDLE THE REQUEST

FIG. 10

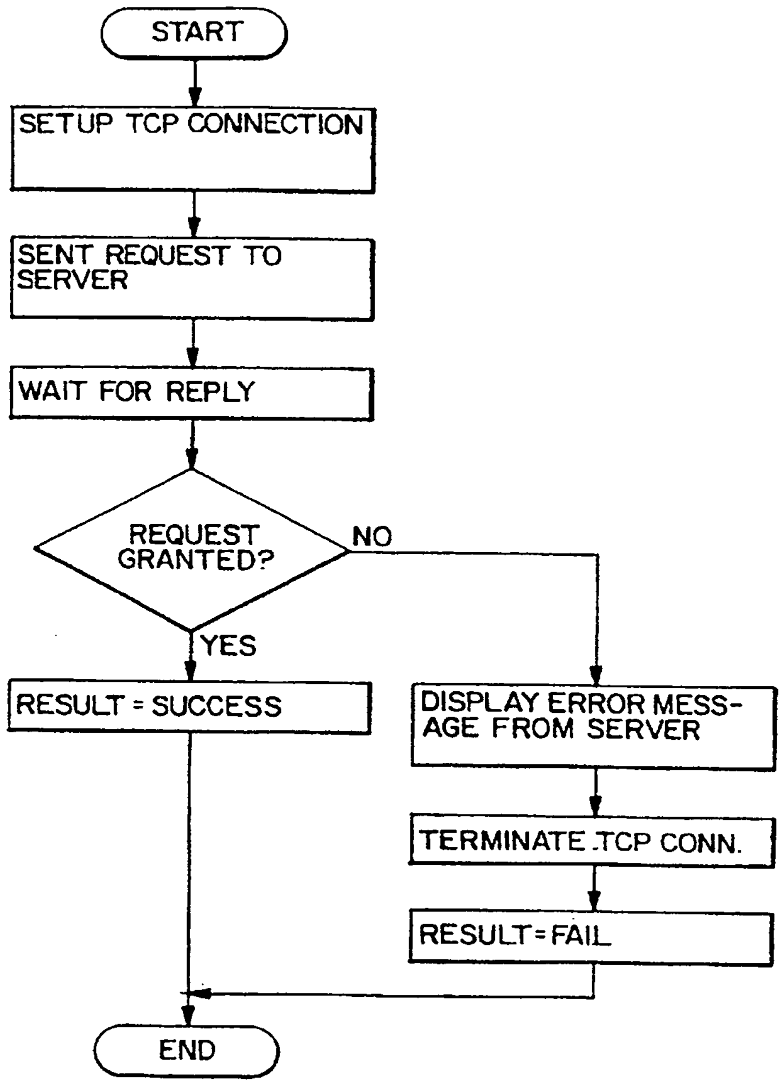

START
SETUP TCP CONNECTION
SENT REQUEST TO SERVER
WAIT FOR REPLY
REQUEST GRANTED?
NO
YES
RESULT = SUCCESS
DISPLAY ERROR MESSAGE FROM SERVER
TERMINATE TCP CONN.
RESULT = FAIL
END

FIG. 11

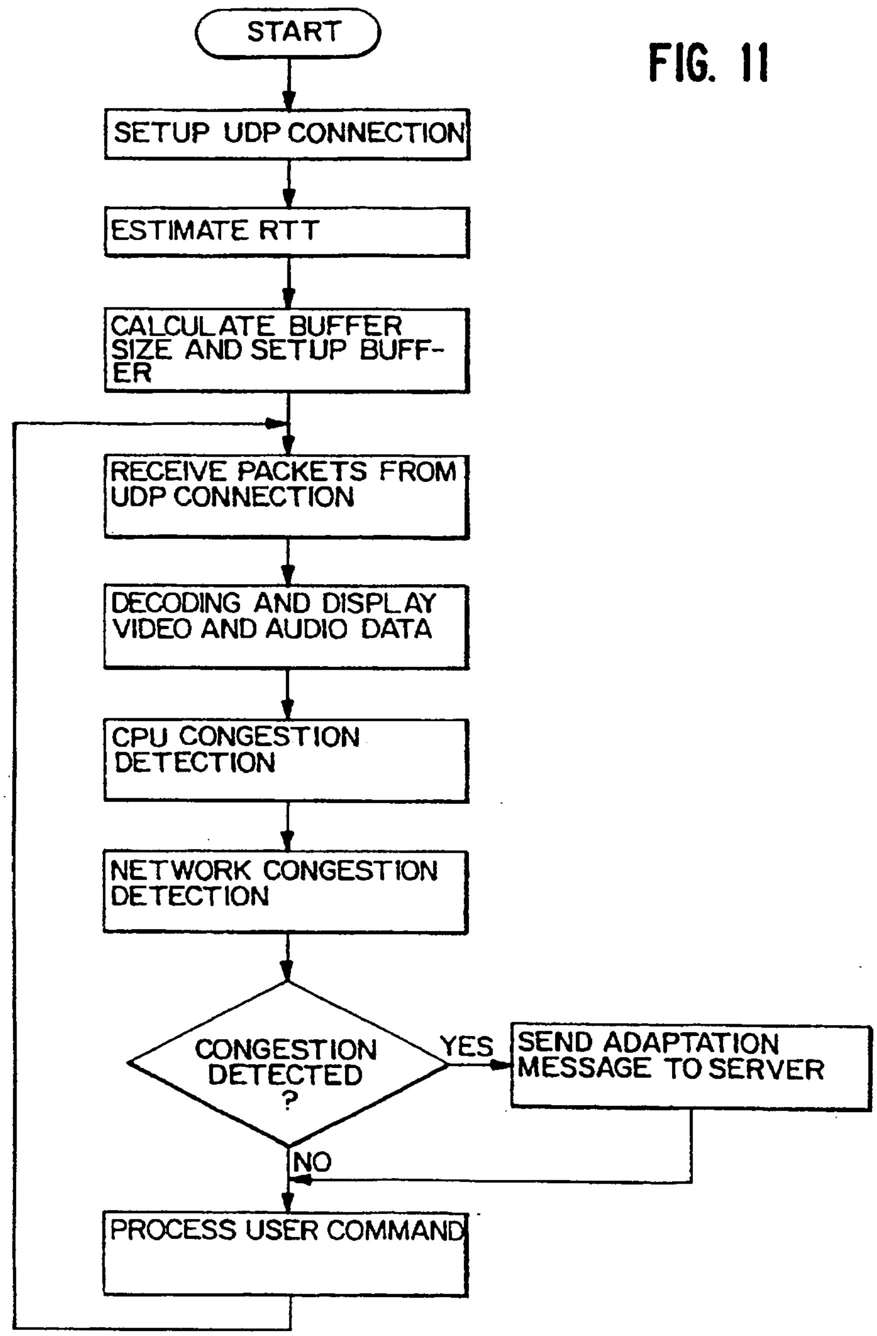

START
SETUP UDP CONNECTION
ESTIMATE RTT
CALCULATE BUFFER SIZE AND SETUP BUFF-ER
RECEIVE PACKETS FROM UDP CONNECTION
DECODING AND DISPLAY VIDEO AND AUDIO DATA
CPU CONGESTION DETECTION
NETWORK CONGESTION DETECTION
CONGESTION DETECTED ?
YES
SEND ADAPTATION MESSAGE TO SERVER
NO
PROCESS USER COMMAND

FIG. 13

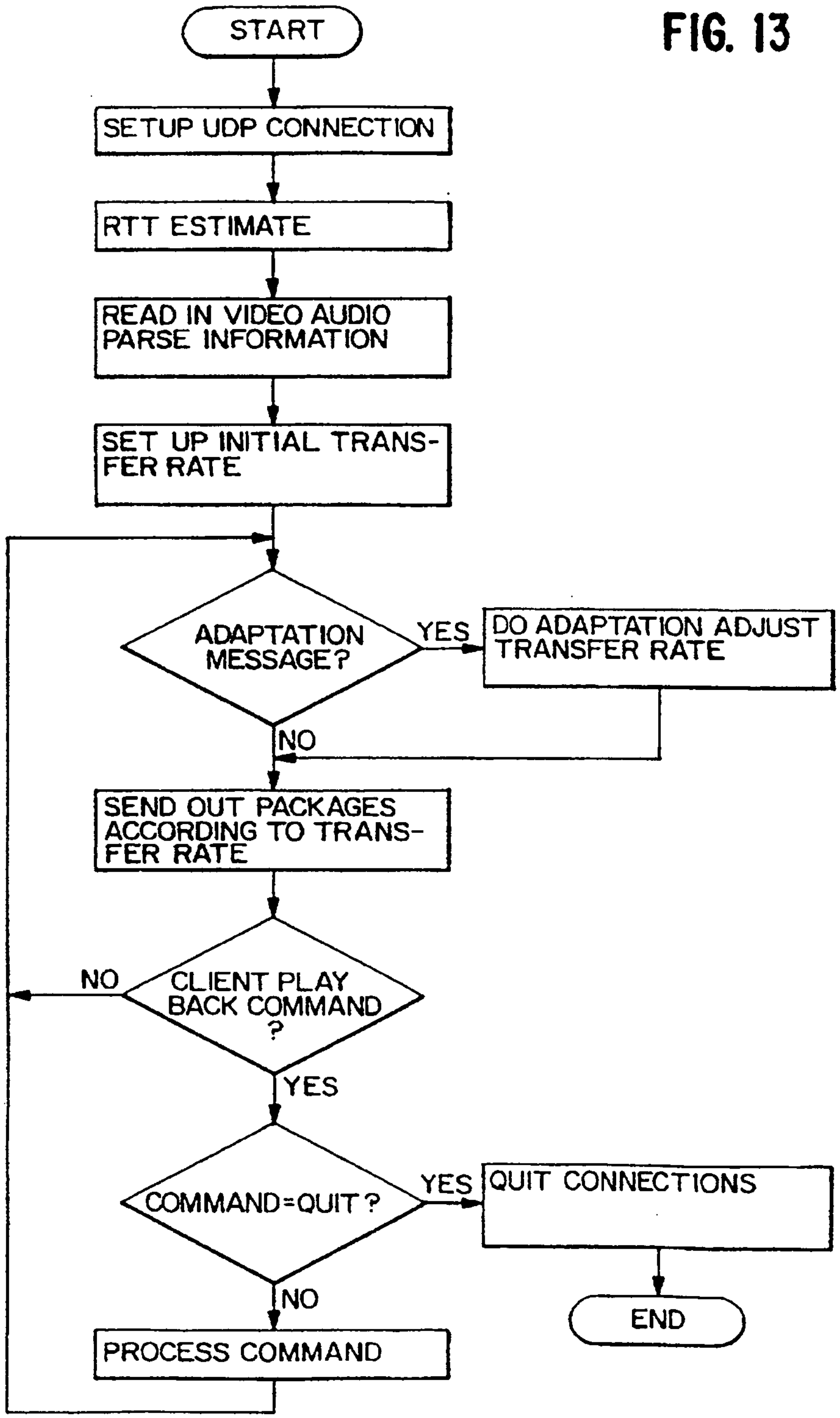
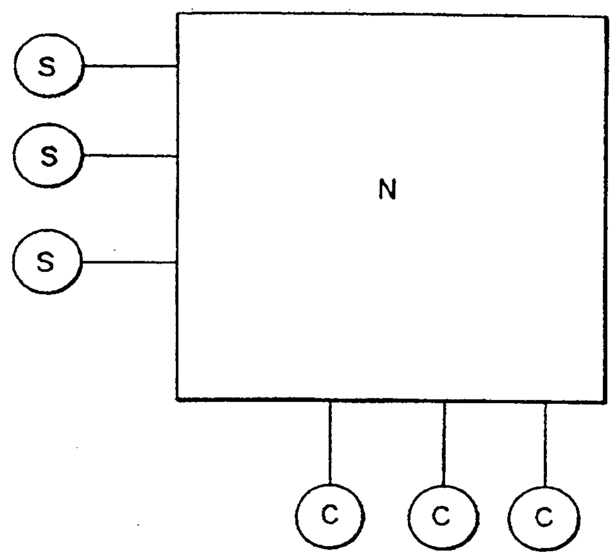

START
SETUP UDP CONNECTION
RTT ESTIMATE
READ IN VIDEO AUDIO PARSE INFORMATION
SET UP INITIAL TRANSFER RATE
ADAPTATION MESSAGE?
YES
DO ADAPTATION ADJUST TRANSFER RATE
NO
SEND OUT PACKAGES ACCORDING TO TRANSFER RATE
NO
CLIENT PLAY BACK COMMAND ?
YES
COMMAND=QUIT?
YES
QUIT CONNECTIONS
END
NO
PROCESS COMMAND

FIG. 14



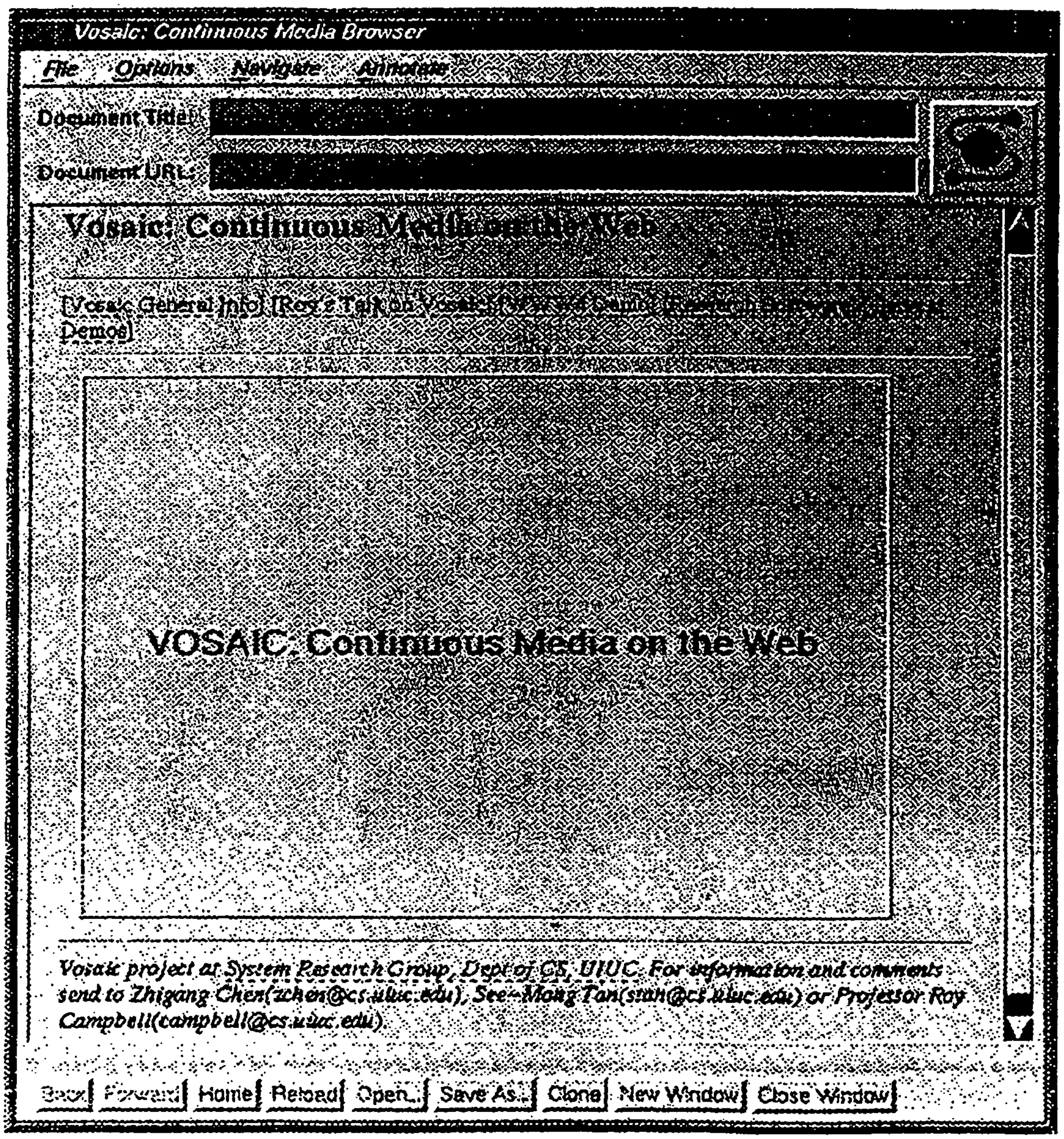

Vosaic: Continuous Media Browser
File Options Navigate Annotate
Document Title:
Document URL:
Vosaic: Continuous Media on the Web
VOSAIC: Continuous Media on the Web
Vosaic project at System Research Group, Dept of CS, UIUC. For information and comments send to Zhigang Chen(zchen@cs.uiuc.edu), See-Mong Tan(stan@cs.uiuc.edu) or Professor Roy Campbell(campbell@cs.uiuc.edu).
Back Forward Home Reload Open... Save As... Clone New Window Close Window

FIG.15A

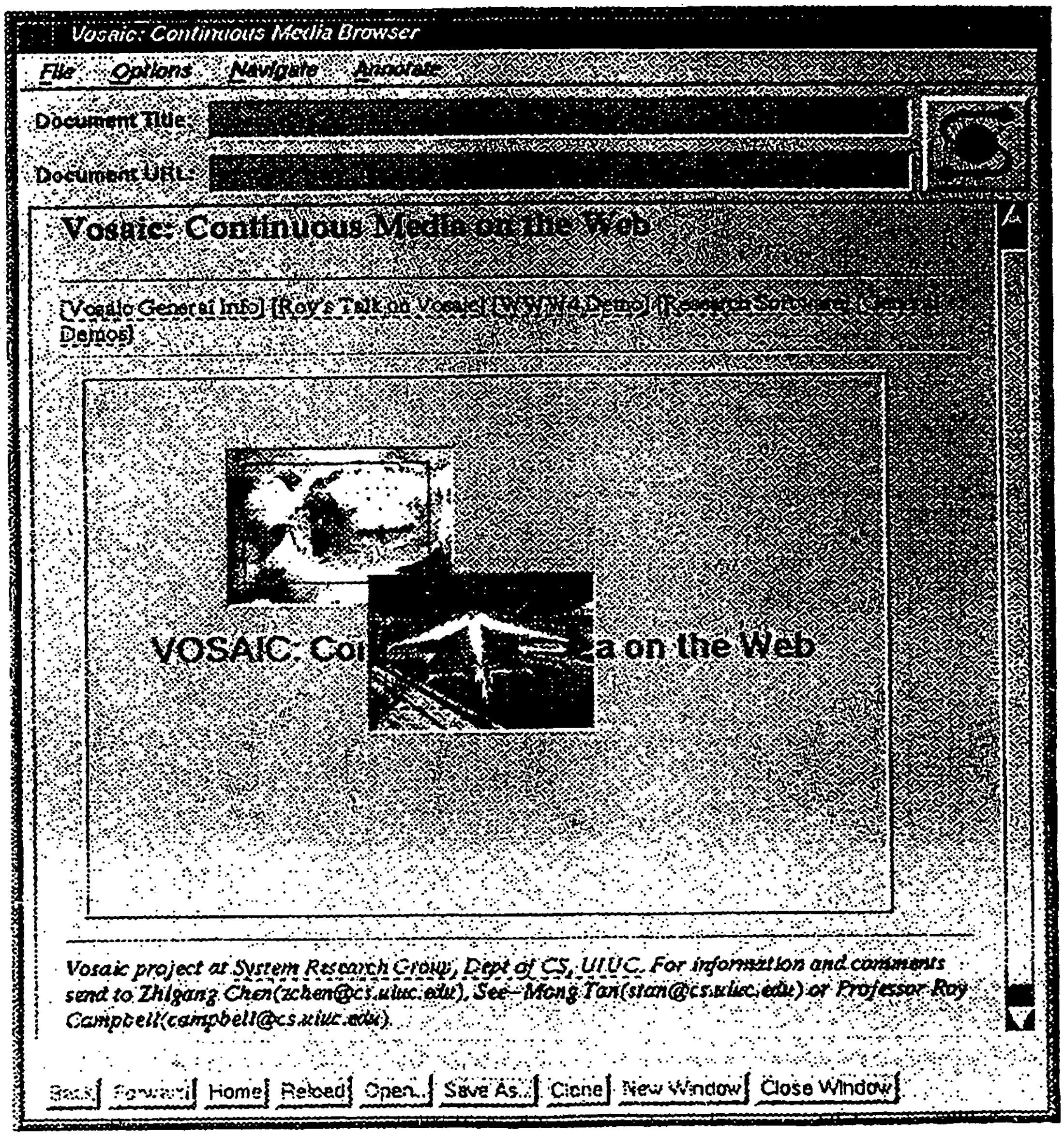

Vosaic: Continuous Media Browser
File Options Navigate Annotate
Document Title:
Document URL:
Vosaic: Continuous Media on the Web
Demos]
VOSAIC: Co a on the Web
Vosaic project at System Research Group, Dept of CS, UIUC. For information and comments send to Zhigang Chen(zchen@cs.uiuc.edu), See-Mong Tan(stan@cs.uiuc.edu) or Professor Roy Campbell(campbell@cs.uiuc.edu).
Home Reload Open... Save As... Clone New Window Close Window

FIG.15B

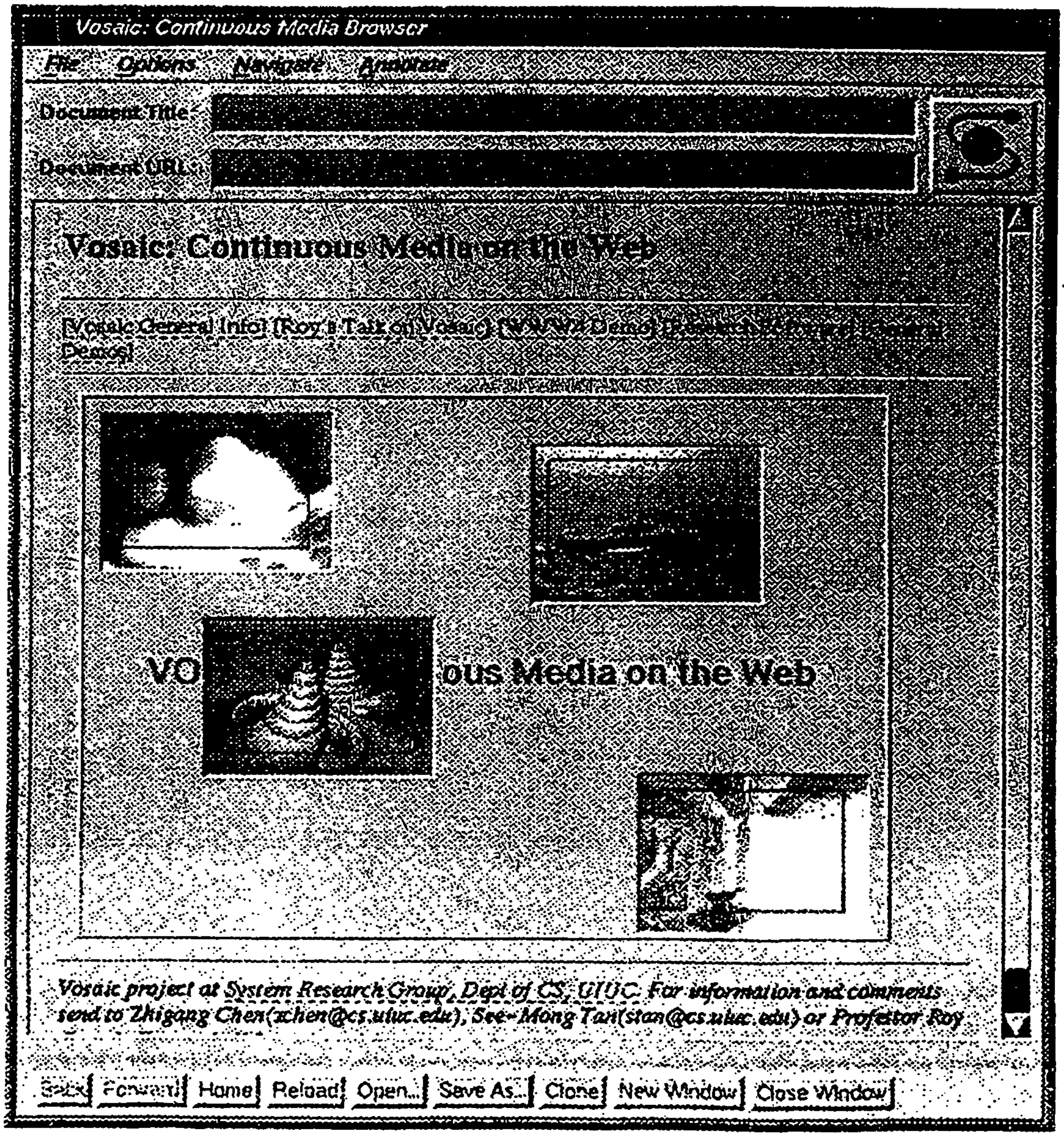

Vosaic: Continuous Media Browser
File Options Navigate Annotate
Document Title:
Document URL:
Vosaic: Continuous Media on the Web
[Vosaic General Info] [Roy's Talk on Vosaic]
ous Media on the Web
Vosaic project at System Research Group, Dept of CS, UIUC. For information and comments send to Zhigang Chen(zchen@cs.uiuc.edu), See-Mong Tan(stan@cs.uiuc.edu) or Professor Roy
Home Reload Open... Save As... Clone New Window Close Window

FIG.15C

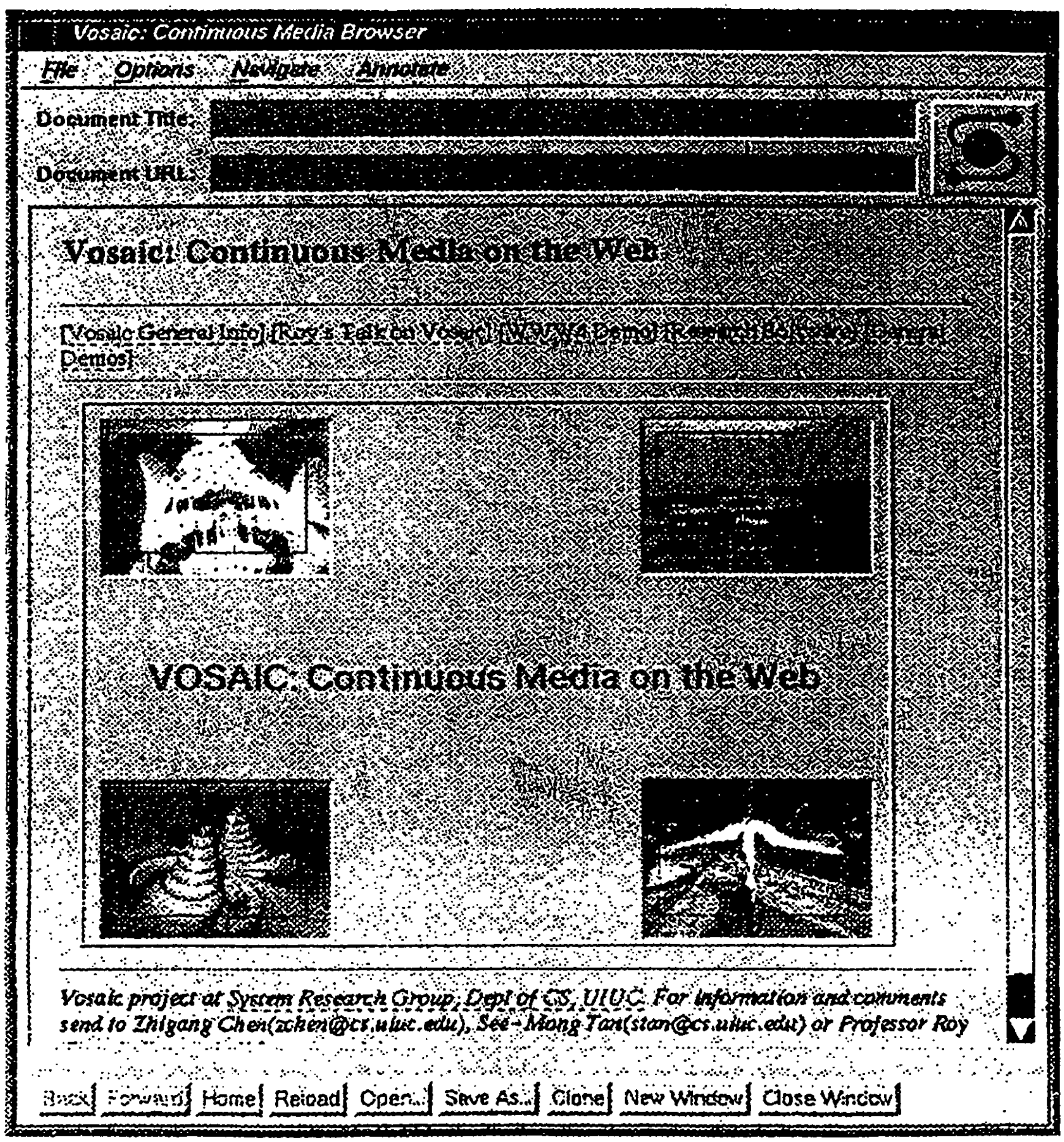

Vosaic: Continuous Media Browser
File Options Navigate Annotate
Document Title:
Document URL:
Vosaic: Continuous Media on the Web
VOSAIC: Continuous Media on the Web
Vosaic project at System Research Group, Dept of CS, UIUC. For information and comments send to Zhigang Chen(zchen@cs.uiuc.edu), See-Mong Tan(stan@cs.uiuc.edu) or Professor Roy
Back Forward Home Reload Open... Save As... Clone New Window Close Window

FIG. 15D

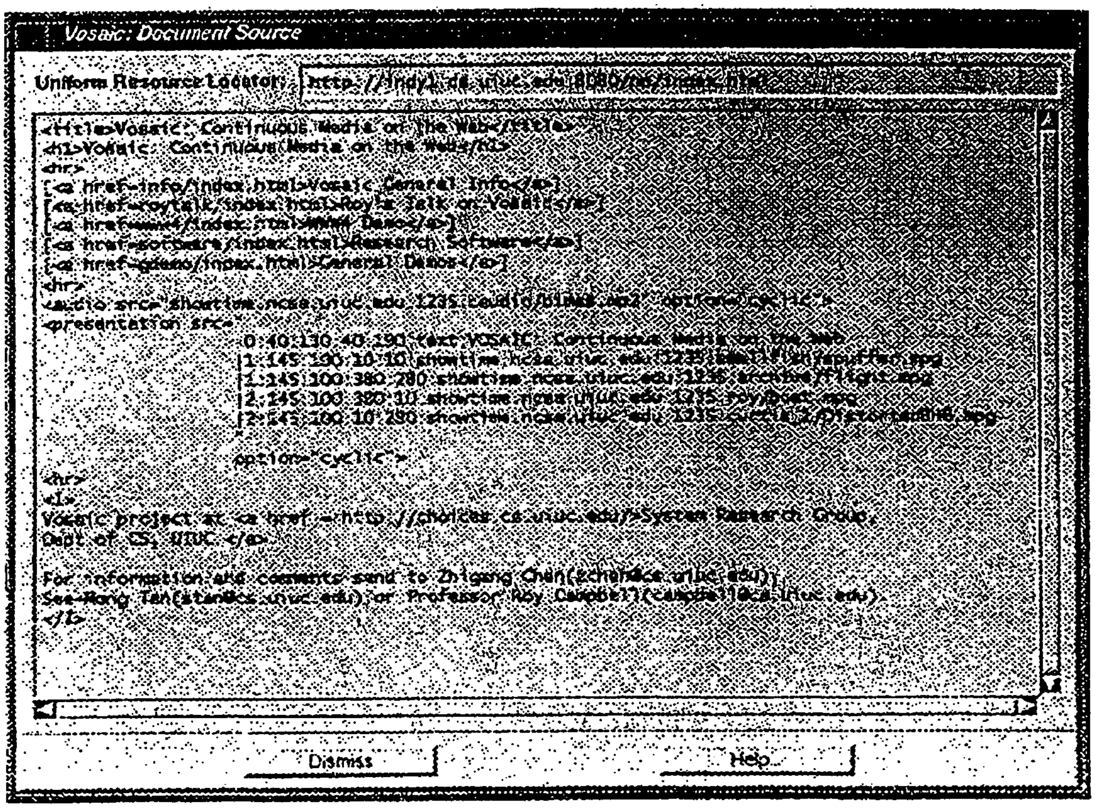

Vosaic: Document Source
Uniform Resource Locator:
<title>Vosaic: Continuous Media on the Web</title>
<h1>Vosaic: Continuous Media on the Web</h1>
<hr>
<hr>
<presentation src=
option="cyclic">
<hr>
For information and comments send to Zhigang Chen
Dismiss
Help

FIG.15E

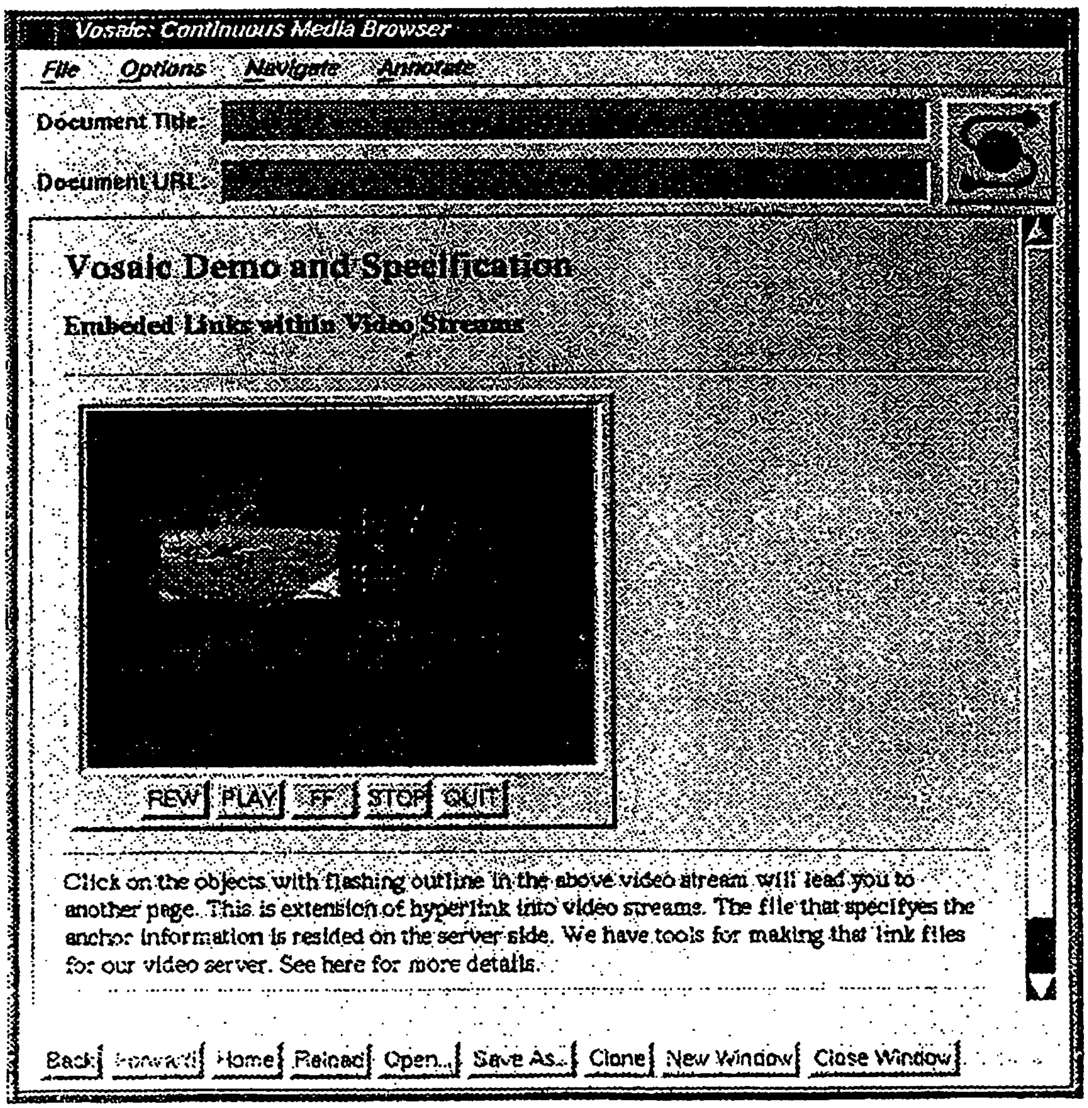

Vosaic: Continuous Media Browser
File Options Navigate Annotate
Document Title:
Document URL:
Vosaic Demo and Specification
Embeded Links within Video Streams
REW PLAY FF STOP QUIT
Click on the objects with flashing outline in the above video stream will lead you to another page. This is extension of hyperlink into video streams. The file that specifyes the anchor information is resided on the server side. We have tools for making that link files for our video server. See here for more details.
Back Forward Home Reload Open... Save As... Clone New Window Close Window

FIG.15F

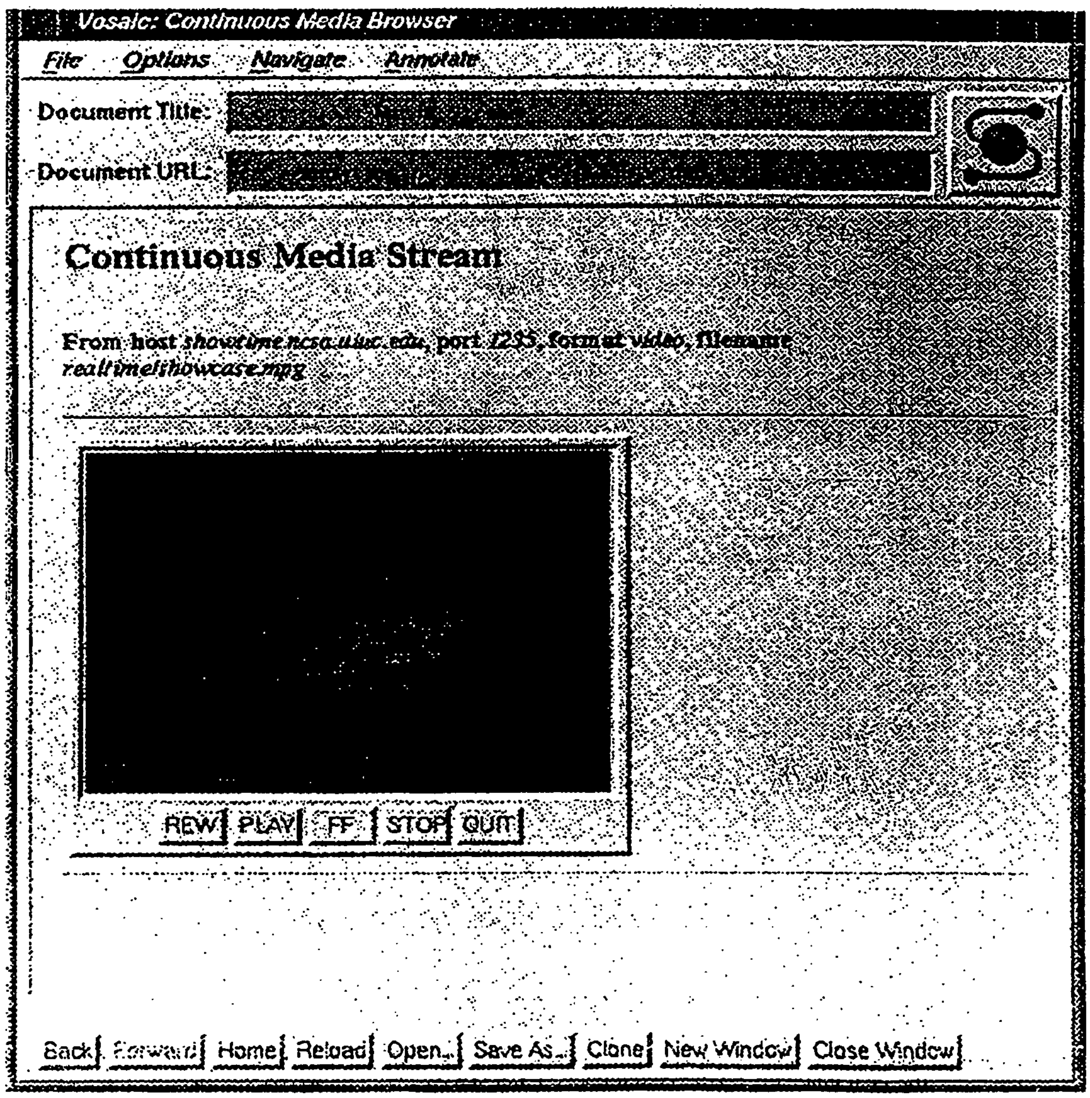

Vosaic: Continuous Media Browser
File Options Navigate Annotate
Document Title:
Document URL:
Continuous Media Stream
REW PLAY FF STOP QUIT
Back Forward Home Reload Open... Save As... Clone New Window Close Window

FIG. 15G

FIG. 16

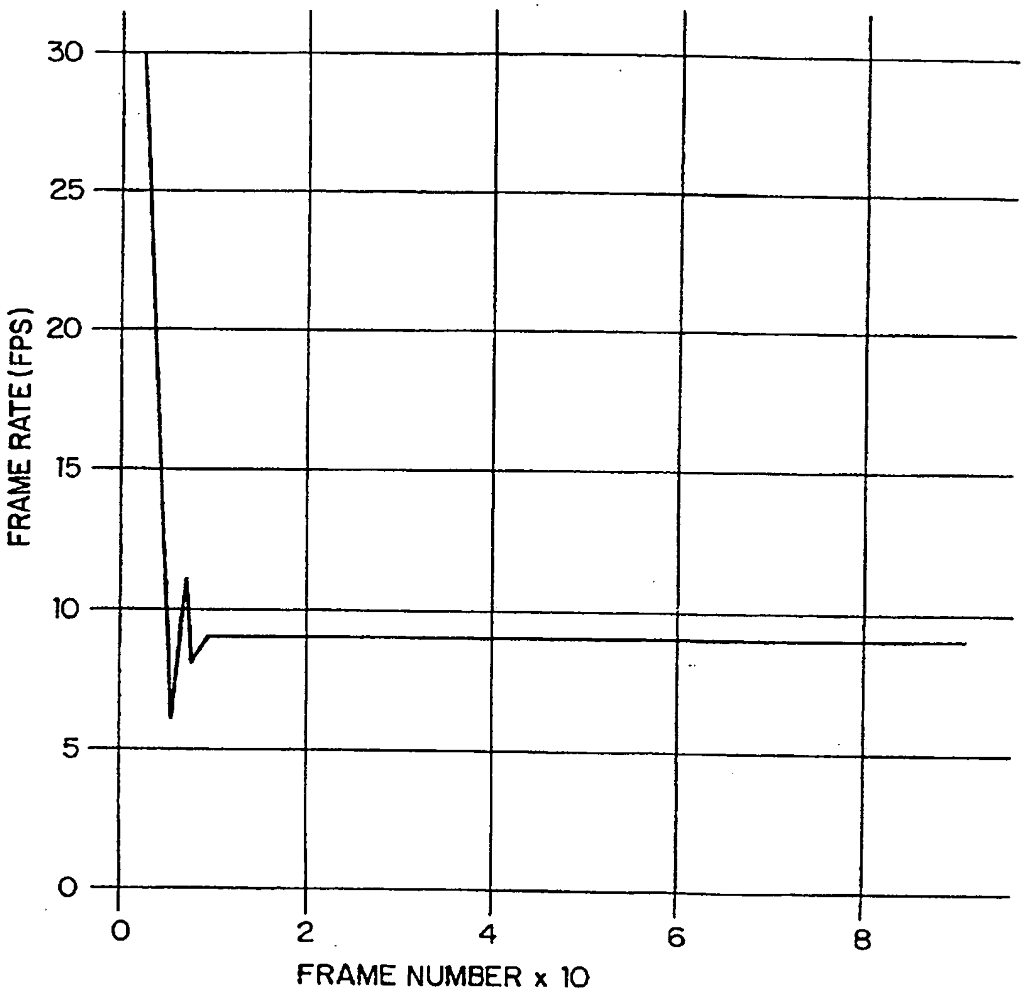


FIG. 17

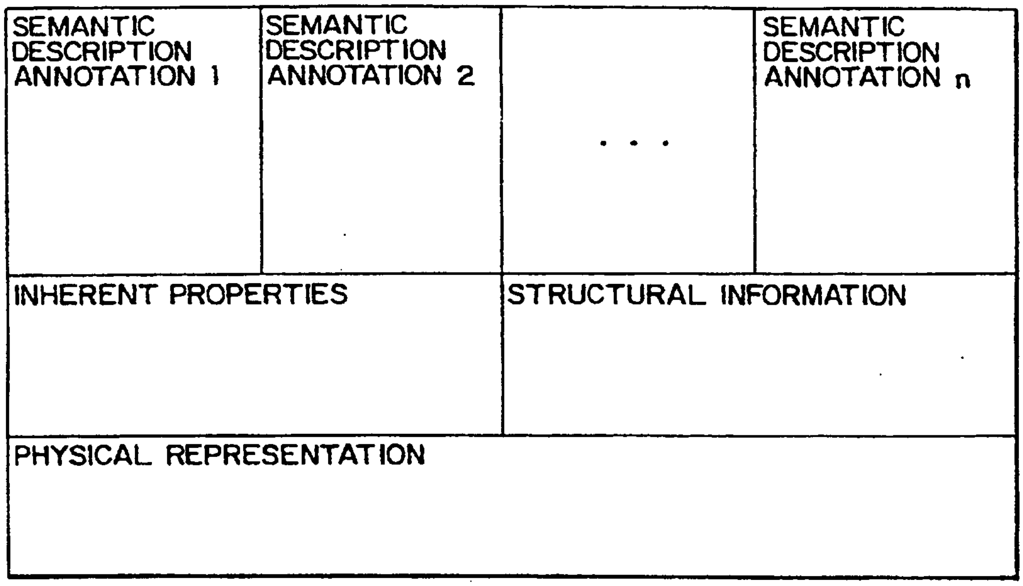

SEMANTIC DESCRIPTION ANNOTATION 1
SEMANTIC DESCRIPTION ANNOTATION 2
. . .
SEMANTIC DESCRIPTION ANNOTATION n
INHERENT PROPERTIES
STRUCTURAL INFORMATION
PHYSICAL REPRESENTATION

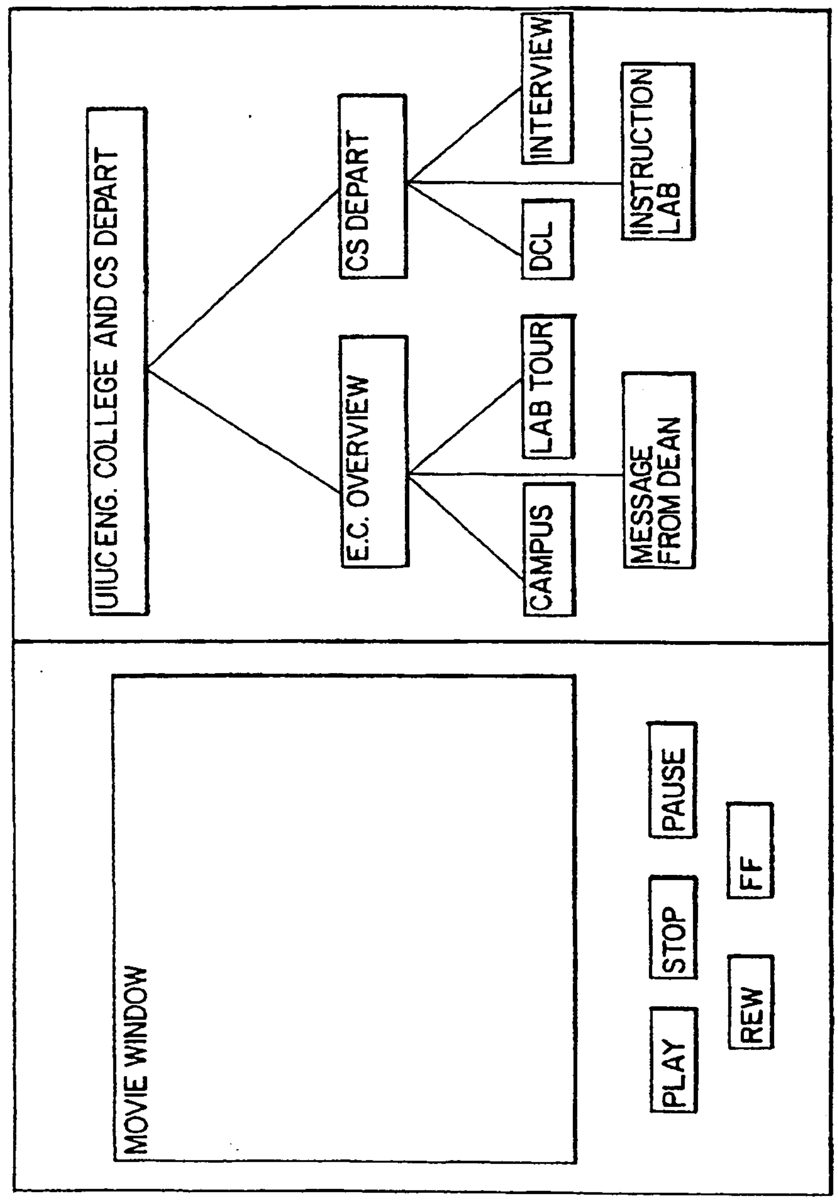
FIG. 18

MOVIE: ENGINEERING COLLEGE AND CS DEPARTMENT AT UIUC	
CLIPS	SHOTS
ENGINEERING COLLEGE OVERVIEW (FRAMES 1-6355)	CAMPUS OVERVIEW (1-1203)
	MESSAGE FROM DEAN (1204-2566)
	ONE LAB TOUR (2567-4333)
	• • •
COMPUTER SCIENCE DEPARTMENT (FRAMES 6356-12003)	DCL TOUR AND OVERVIEW (6400-8000)
	INSTRUCTION LAB TOUR (8001-9654)
	INTERVIEW WITH A UNDERGRADUATE STUDENT (9655-11000)
	• • •

FIG. 19

SHOTS	FRAMES	KEY WORDS
CAMPUS OVERVIEW	1-1203	UIUC, ENGINEERING CAMPUS, CAMPUS
MESSAGE FROM DEAN	1204-2566	UIUC, ENGINEERING, DEAN, TALK
ONE LAB TOUR	2567-4333	UIUC, ENGINEERING, LAB TOUR
DCL TOUR AND OVERVIEW	6400-8000	UIUC, CS DEPART, DCL, TOUR, OVERVIEW
INSTRUCTIONAL LAB TOUR	8001-9654	UIUC, CS DEPART, TOUR, INSTRUCTIONAL LAB
INTERVIEW WITH A UNDERGRADUATE STUDENT	9655-11000	UIUC, CS DEPART, INTERVIEW

FIG. 20


UIUC ENG. COLLEGE AND CS DEPART
E.C. OVERVIEW
CS DEPART
CAMPUS
LAB TOUR
MESSAGE FROM DEAN
DCL
INTERVIEW
INSTRUCTION LAB
MOVIE WINDOW
PLAY
STOP
PAUSE
REW
FF

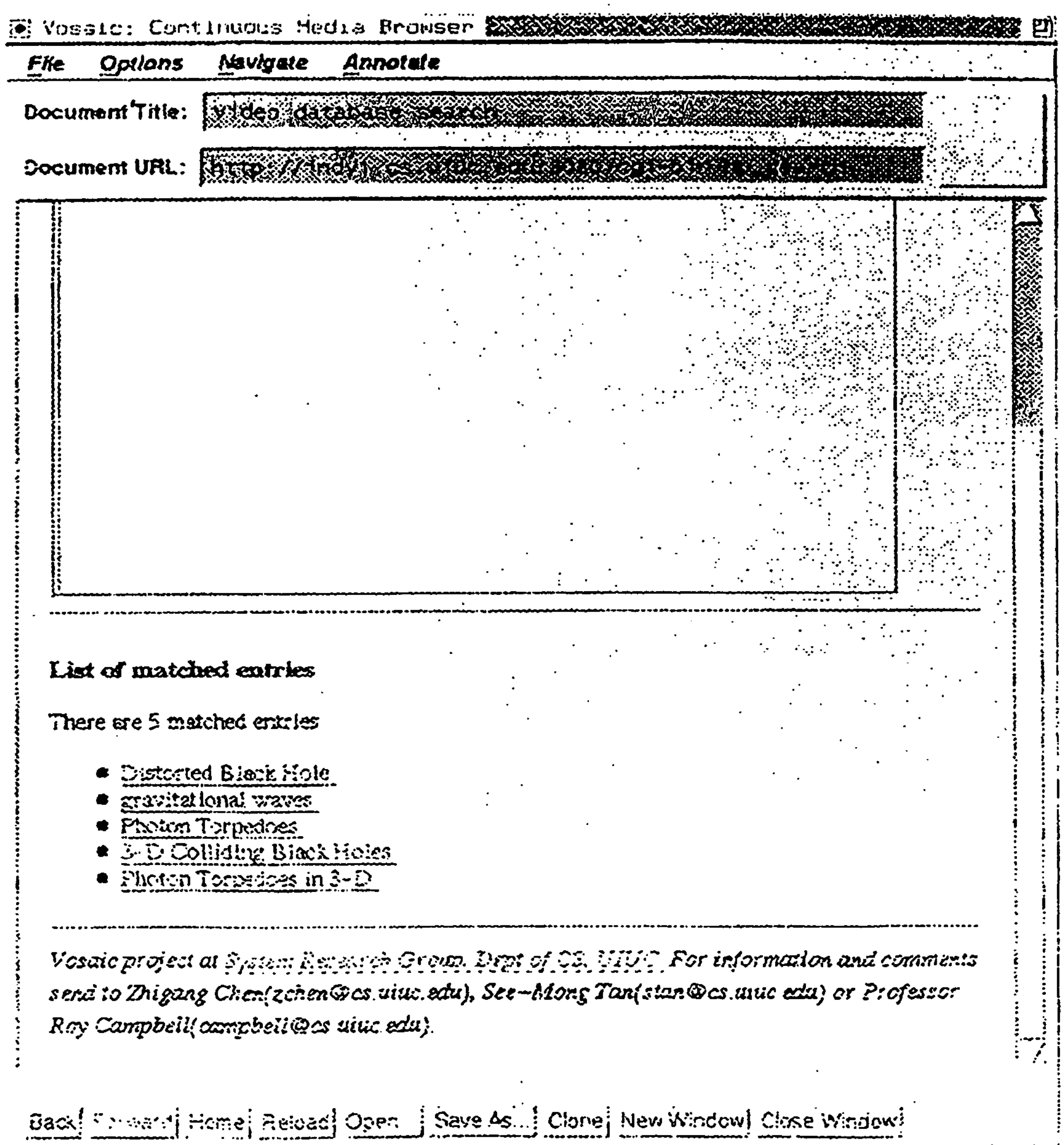

Vosaic: Continuous Media Browser
File
Options
Navigate
Annotate
Document Title:
video database search
Document URL:
List of matched entries
There are 5 matched entries
Distorted Black Hole
gravitational waves
Photon Torpedoes
3-D Colliding Black Holes
Photon Torpedoes in 3-D
Vosaic project at System Research Group, Dept of CS, UIUC. For information and comments send to Zhigang Chen(zchen@cs.uiuc.edu), See-Mong Tan(stan@cs.uiuc.edu) or Professor Roy Campbell(campbell@cs.uiuc.edu).
Back
Home
Reload
Open
Save As...
Clone
New Window
Close Window

FIG.21

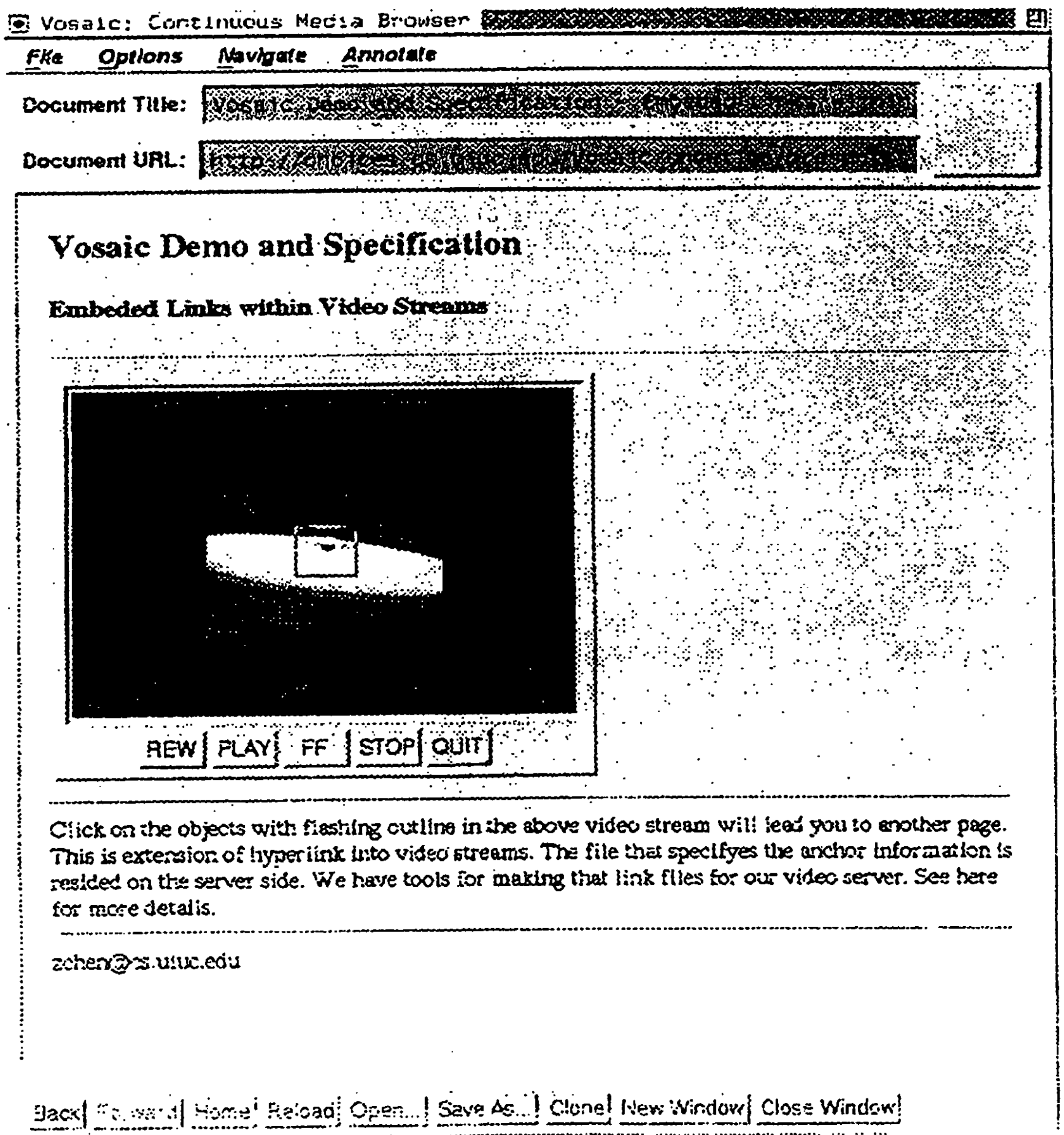

Vosaic: Continuous Media Browser
File
Options
Navigate
Annotate
Document Title:
Document URL:
Vosaic Demo and Specification
Embeded Links within Video Streams
REW
PLAY
FF
STOP
QUIT
Click on the objects with flashing outline in the above video stream will lead you to another page. This is extension of hyperlink into video streams. The file that specifyes the anchor information is resided on the server side. We have tools for making that link files for our video server. See here for more details.
zchen@cs.uiuc.edu
Back
Home
Reload
Open...
Save As...
Clone
New Window
Close Window

FIG.22

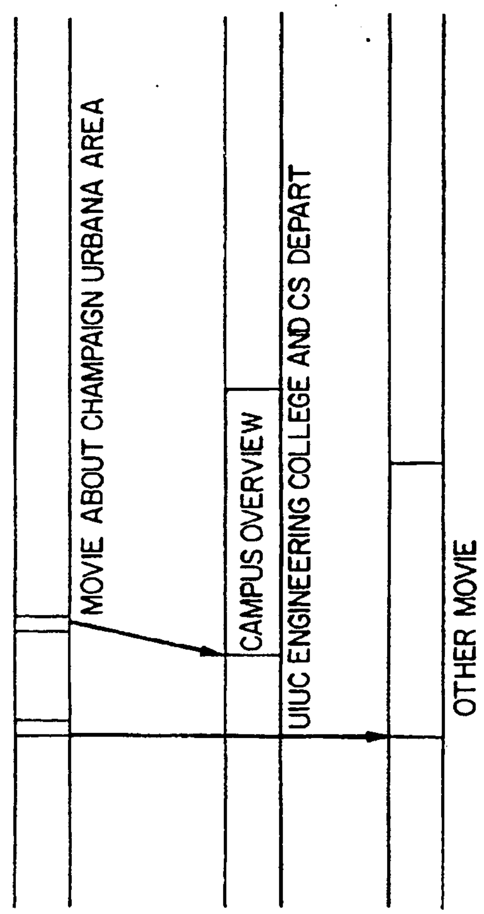

MOVIE ABOUT CHAMPAIGN URBANA AREA
CAMPUS OVERVIEW
UIUC ENGINEERING COLLEGE AND CS DEPART
OTHER MOVIE

FIG. 23

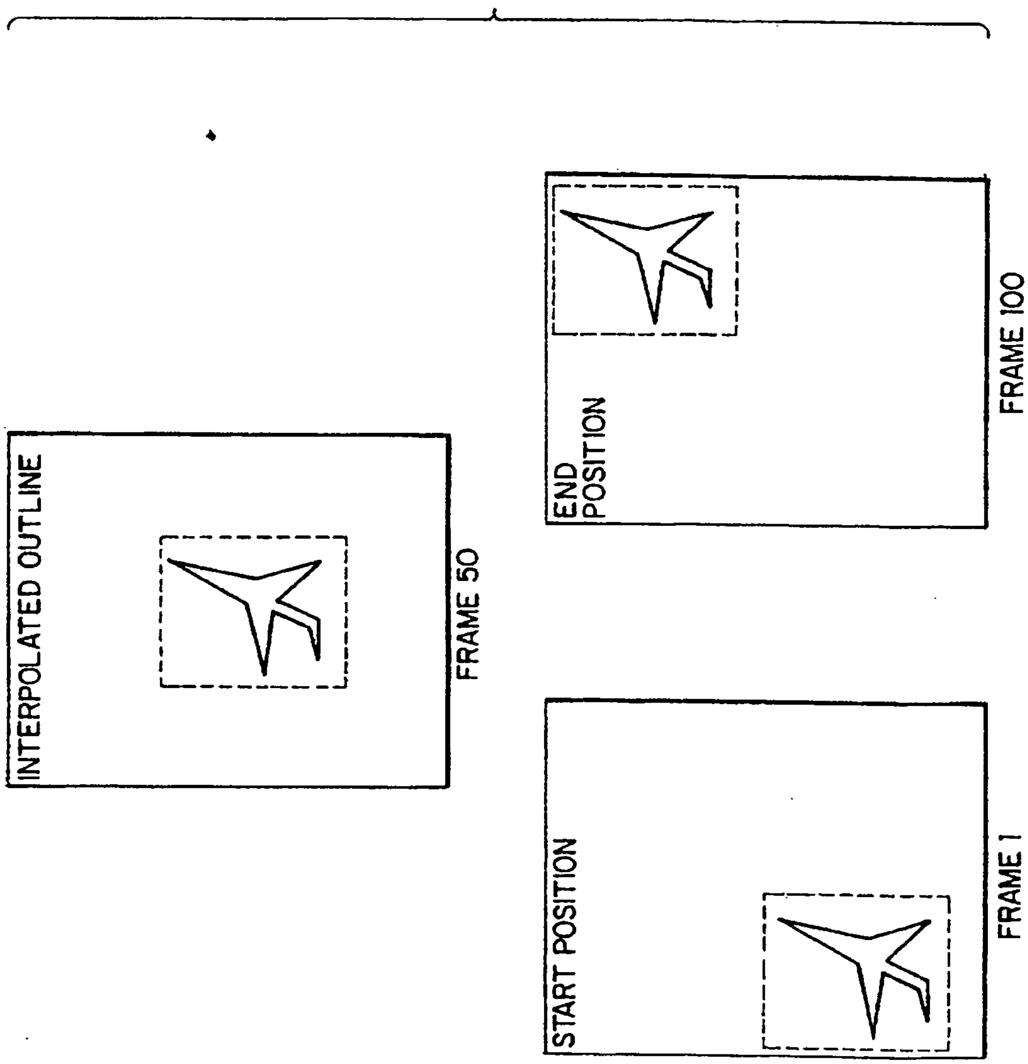

INTERPOLATED OUTLINE
FRAME 50
END POSITION
FRAME 100
START POSITION
FRAME 1

FIG. 24